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Do People With Aphasia Interpret Road Signs Differently Than People Without Aphasia?

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DO PEOPLE WITH APHASIA INTERPRET ROAD SIGNS DIFFERENTLY THAN PEOPLE WITHOUT APHASIA?

A Thesis

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For my mother, Erin Brown,
who told me to “get an education.”
Thank you.

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LIST OF ACRONYMS

AG	Aphasia Group
ALPS	Aphasia-Language Performance Scales
ASA	American Stroke Association
ASHA	American Speech-Language-Hearing Association
COR Lab	Communication Outcome Research Laboratory
CVA	Cerebrovascular Accident
CG	Control Group
LSU-SLHC	Louisiana State University- Speech, Language, Hearing Clinic
M	Mean
MANOVA	Multivariate Analysis of Variance
NAA	National Aphasia Association
NIH	National Institutes of Health
PWA	People with Aphasia
SD	Standard Deviation
SDSA	Stroke Drivers' Screening Assessment

ABSTRACT

Purpose: This study increased our understanding of how aphasia may affect interpretation of road signs.

Background: Despite aphasia's theoretical effects on road sign comprehension and promising initial findings in studies that investigated driving and aphasia, the literature examining aphasia and road signs has been sparse. Research has shown that aphasia may have some effect on road sign interpretation. However, more study is needed regarding both accuracy and response time to road sign interpretation, which are equally important for safe driving.

Methods: This was a prospective, between group study that used data collected from a larger study by Donovan, Savage, Varnado, & Brown (2014). This study aimed to determine if presence of aphasia had an effect on the accuracy and response time of road sign interpretation in a sample of 10 adults with aphasia versus 10 adults in neurologically normal control group. The participants were asked to choose the correct interpretation of pictures of road signs from three choices. A MANOVA was conducted to compare the effect of aphasia on accuracy and response time ($\alpha = .05$).

Results: Aphasia significantly impacted accuracy and response time of road sign interpretation (V = .996, $F(2, 17) = 8.446$, $p = .003$). The aphasia group was (a) less accurate ($M = 28.60$) than the neurological normal control group ($M = 32.30$; $p = .001$); and (b) slower ($M = 2777.62$ ms) than the neurological normal control group ($M = 1211.58$ ms; $p = .036$). Visual inspection of the data also showed the aphasia group was less accurate and had longer response times interpreting signs that were linguistically dense or had greater symbolic complexity.

Discussion: The role of healthcare providers, including speech-language pathologists, in advising people with aphasia about return to driving is not well documented. The present study suggests

aphasia may have an effect on driving and therefore, speech-language pathologists may serve an important role in helping people with aphasia make informed choices about return to driving. More study, however, is needed to investigate the profile of deficits that contribute to poor road sign interpretation and to build upon and support the present study's results.

INTRODUCTION

Driving is important for Americans even as they reach later decades of life. Access to transportation is not only significant to the physical health, but also the emotional well-being of older adults (Carp, 1988; Eisenhandler, 1990; Johnson, 2003; Coughlin, 2004; Whitehead et al., 2006). Transportation is necessary to complete many life-sustaining activities, e.g. access to healthcare, banking, and grocery shopping (Carp, 1988). Beyond physical needs, older adults view ability to drive as an essential part of their identity (Eisenhandler, 1990). Driving is linked with feelings of independence and freedom (Carp, 1988; Eisenhandler, 1990; Johnson, 2003; Coughlin, 2004; Whitehead et al., 2006). However, research shows health conditions will eventually impact most older adults' ability to use an automobile safely and efficiently (Dickerson et al., 2007). The physical and mental difficulties of any illness, but especially the chronic conditions common later in life, may hinder the use multiple skills needed to drive.

Aphasia is a common health condition that results from a stroke causing deficits in one or more modalities of language, e.g. reading, writing, speaking, listening (Bhatnagar, 2013; National Aphasia Association, 2011; Papathanasiou & Coppens, 2013). The National Aphasia Association (NAA) reports that 25-40% of people who survive a stroke have aphasia. In the United States, one million people are currently diagnosed with aphasia and 200,000 additional cases occur every year (NAA, 2011). Recovery from aphasia is long term and full restoration of pre-injury language abilities may not be possible (NAA, 2011).

Beyond communicating with loved ones, language needs are prevalent throughout our environment. We listen to news on the radio, read articles on the internet and speak to service providers. Aphasia may affect any or all of these. This study proposes that there is an additional daily activity with a connection to language—driving, where the ability to read and interpret road signs is critical for success and safety.

Alexia, the inability to read, or deficits in reading common to aphasia could impact road sign interpretation. However, a pure alexia diagnosis is not needed to imply road sign interpretation deficits. Applying the connectionist model of reading, a language impairment that is most obvious in other language modalities (speaking, listening, or writing) could also be found in reading through inter-related semantic, phonological, and orthographic processes (Harm & Seidenberg, 1999; Plaut, McClelland, Seidenberg, & Patterson, 1996; Plaut, 1999; Seidenberg & McClelland, 1989). If these processes are slowed or absent, the driver would be unable to accurately or efficiently interpret road signs.

However, traffic signs not only use words but also feature pictographs. Therefore, the pictographic information on road signs could decrease language deficits in people with aphasia (PWA). In a larger sense, traffic signs could be considered an invented symbol system, like language, with rules and conventions. As a symbol system, road signs, too, may be subject to the comprehension difficulties PWA demonstrate. Evidence exists that PWA have difficulty recognizing and interpreting previously familiar symbols including traffic sign stimuli (Dejerine, 1892; Critchley, 1970, p.341-343; Gardner, 1974; Wapner & Gardner, 1981).

Despite the theoretical support for aphasia's effect on road sign interpretation, the current literature on driving rarely includes participants with aphasia. Prior to the larger project that this study takes its data from (Donovan, Savage, Varnado & Brown, 2014), only four studies that examined the driving performance and aphasia were found, and only one study was completed since 2003 (Hartje, Willmes, Pach, & Hannen, 1991; Lebrun, Leleux, Fery, Doms, & Buyssens, 1978; Mackenzie & Paton, 2003; Matsko, Boblitz, Glass, & Rosenthal, 1975). These studies all found that aphasia had a negative effect on variables related to driving performance. However, only two of these studies examined road sign recognition as their focus.

The studies that specifically investigated aphasia and road sign recognition (Lebrun, Leleux, Fery, Doms, & Buyssens, 1978; Mackenzie & Paton, 2003) found that PWA performed worse on tests of road sign recognition but did not fully investigate the road sign interpretation deficit. Lebrun et al. (1978) reported accuracy on their road sign test but not response time, an important variable needed to make decisions quickly when driving. Mackenzie and Paton (2003) assessed both accuracy and response time, but their measures did not assess whether participants understood road sign's function. And while both studies provided valuable information, more research is needed to understand how aphasia impacts road sign recognition, especially in the accuracy and response time of functional interpretation.

Statement of the Problem

Driving ability is important for the physical and emotional well-being of individuals. Aphasia's theoretical effect on road sign interpretation is supported by literature reporting negative effects on driving ability in PWA. However, aphasia's impact on the ability of a person to interpret road signs and therefore, drive safely remains understudied.

A REVIEW OF THE LITERATURE

Driving as an Essential Activity of Daily Life

Driving is important for Americans even as they reach later decades of life. A person in the United States traveled 36.15 miles on average per day in 2009. 88.35% of those miles were traveled in private vehicles. 91.3% of households owned at least one vehicle (Santos, McGuckin, Nakamoto, Gray, & Liss, 2011). Most people continue to drive into and beyond their eighties (Santos et al., 2011). Most miles throughout our lives are traveled for family/personal errands and social/recreational events rather than commuting for employment (Santos et al., 2011). Overall, Americans drive often and continue to do so for most of their lives.

Access to transportation is related to the physical well-being of older adults and driving is often the most appropriate option. Transportation is necessary to complete many life-sustaining activities (e.g. access to healthcare, banking, and grocery shopping; Carp, 1988). For many households, private vehicle ownership is essential due to limited access to or the poor quality of public transport (Johnson, 2003). Routes and stops may be inconvenient or require more walking than is physically possible for older adults. Additionally, rural areas often do not have mass transit systems. Taxis can be prohibitively expensive for many, especially those on fixed incomes (Johnson, 2003). Rides from family and friends can be less limited than mass transit and more cost effective than taxis (Johnson, 2003), but may still be inconvenient and represent a loss of independence and decreased quality of life.

Furthermore, driving contributes to the emotional well-being of older adults. Driving is linked to feelings of independence and freedom (Carp, 1988; Eisenhandler, 1990; Johnson, 2003; Coughlin, 2004;Whitehead et al., 2006). Concurrently, driving cessation causes feelings of uselessness, worthlessness, depression, and even loss of identity (Carp, 1988; Whitehead et al., 2006). Eisenhandler (1990; p.6) wrote that driving “preserves a sense of control and independence”. Bryant, Corbett, and Kutner (2001) found that older people defined health as “going and doing something meaningful.” Driving cessation limits access to meaningful participation in activities like paid or volunteer work (Curl, Stowe, Cooney, & Proulx, 2014). With such clear differences between feelings associated with driving and not driving, driving’s importance to older adults should not be minimized.

Driving is an activity of daily life that is essential to the physical and emotional well-being of older adults. Yet for most, health conditions will eventually impact their ability to use an automobile safely (Dickerson et al., 2007). The current study examines how aphasia, a common condition following stroke, affects driving. In the following sections, I will describe aphasia and further characterize the relationship between this condition and driving.

Aphasia

Characteristics of Aphasia

The term aphasia means “speechlessness” in ancient Greek. A closer modern translation of the term could perhaps be “languagelessness,” as aphasia refers not only to difficulties expressing spoken language but also extends to understanding and across other language modalities (reading, writing, listening). Most persons with aphasia do not lose language entirely, but show deficits in one or more modes of expression and comprehension (reading, writing, speaking, listening). Aphasia may co-occur with other cognitive or motor deficits, but it is not caused by them (Martin & Allen, 2008; Fucetola et al., 2009; Murray, 2012; Papathanasiou & Coppens, 2013).

Aphasia is the result of acquired neurological damage to the language-dominate hemisphere of the brain, but is most often caused by a cerebrovascular accidents (CVAs), (Papathanasiou & Coppens, 2013; Chapey 2008). CVAs, commonly called strokes, are focal failures of the vascular system of the brain resulting in sudden neurological deficits (Bhatnagar, 2013). The American Stroke Association (ASA) (2013) reports that CVAs are the fourth leading cause of death in the United States. 795,000 people in the United States will experience a new or recurrent stroke per year, and one stroke occurs every forty seconds (ASA, 2013). On a local level, Louisiana is located in the United States' "Stroke Belt"—a geographical area that has a 10% greater risk of CVA than the rest of the country (National Heart, Lung, and Blood Institute, 2009). In 2005, the stroke mortality rate in Louisiana was 17% above the national average (Louisiana Department of Health and Hospitals, 2008). However, for those who do survive stroke, recovery of neurological deficits can be a long process. The National Aphasia Association (NAA) reports that 25-40% of people who survive a CVA have aphasia. In the United States, one million people are currently diagnosed with aphasia and 200,000 additional cases occur every year (NAA, 2011). Recovery from aphasia is long term and full restoration of pre-injury language abilities may not be possible (NAA, 2011).

Beyond simply communicating with loved ones, language needs are prevalent throughout our environment. We listen to news on the radio, read articles on the Internet, and speak to service providers. This study proposes that there is a regular activity with a less obvious but no less important connection to language—driving.

Effect of Aphasia on Driving

Language Impairment

Alexia is a reading impairment caused by acquired neurological damage that affects the interpretation of written materials and therefore affects reading comprehension. Driving requires the perception and interpretation of written material (i.e. road signs) in a time sensitive process.

Therefore, types of alexia that commonly occur with aphasia could be responsible for difficulty driving. Other language modalities (speaking, listening and writing) can be linked to reading impairment using the connectionist model of reading.

Connectionist Model of Reading. Connectionist models of reading assert that reading involves the interaction of orthographic, semantic, and phonological processing (Figure 1; Harm & Seidenberg, 1999; Plaut, McClelland, Seidenberg, & Patterson, 1996; Plaut, 1999; Seidenberg & McClelland, 1989). Language users interpret spoken or written language by "comparing" the media's characteristics to known orthographic, semantic, and phonological characteristics and analyze for similarities (Riley & Kendall, 2013).

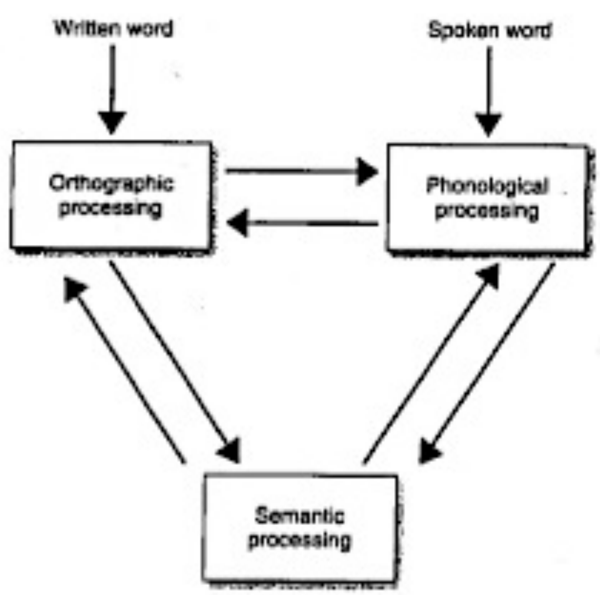

Figure 1 Connectionist Model Triangle (Riley & Kendall, 2013; Seidenberg & McClelland, 1989)

In an example offered by Riley and Kendall (2013), reading a written word aloud and understanding its meaning first requires searching for similar grapheme representations in previously processed orthographic contexts. The reader accesses the meaning of the word in known semantic representations (Riley & Kendall, 2013). Concurrently, the phonological representations associated with the material's graphemes are retrieved and used to say the word aloud (Riley & Kendall, 2013).

The connectionist model is important to this discussion of aphasia because it bridges the reading modality to all other modes of language (speaking, listening, and writing). A language impairment that is most obvious in speech could also be found in reading through altered semantic or phonological processes. The reading impairment need not be total and functional reading could be intact. Instead, a breakdown in access to pre-morbid linguistic information affects the efficiency of the processing of written material. An individual with aphasia can only rely on comparing the current stimuli to what remains accessible, which would slow down the ability to quickly interpret material. An individual with aphasia can still use unaffected channels but would require additional time compared to their pre-morbid abilities.

Symbol Interpretation in PWA

Beyond linguistic information, road signs may present symbolic material. Traffic signs not only use words but alternatively or additionally feature pictographs. In a larger sense, traffic signs could be considered an arbitrary symbol system with rules and conventions similar to a language, e.g. in use of color, shape, or image. Considering that aphasia is a language disorder, the pictographic information in road signs could overcome language deficits in PWA. However, research supports that even when images supplement comprehension, PWA have deficits in symbol interpretation.

PWA may have difficulty recognizing and interpreting previously familiar symbols. Early sources suggested that musicians with aphasia had difficulty interpreting musical notes (Dejerine, 1892) and, more recently, Critchley reported sailors with aphasia have deficits with decoding signal flags (1970, p.341-343). Gardner investigated the naming and recognition of sixty-six written symbols to a neurological normal group, a brain-damaged group without aphasia, and groups of PWA with anterior and posterior brain damage (1974). He also examined two smaller groups, one whose primarily complaint was anomia and one whose primarily complaint was alexia. Recognition was measured as the total number of symbols that were accurately identified during the experiment with or without multiple-choice cueing. PWA with posterior damage did significantly worse than the other groups. Furthermore, when symbols requiring facial recognition were controlled for, the PWA with anterior damage also made significantly more errors in recognition than neurological normal and persons with right hemisphere damage, which has been more typically associated with visuospatial deficits. In the smaller groups, participants with alexia did as poorly as the participants with anomia at naming symbols–even those symbols that the authors did not consider "verbal." The finding in the alexia group suggested that alexic deficits may go further than the interpretation of written words. Gardner's findings supported that PWA have greater difficulty with the recognition of symbols than neurologically normal people and even those who's lesions have been more typically ascribed to visuospatial deficits (Gardner, 1974).

Wapner and Gardner further investigated visual symbol recognition in PWA in an inpatient hospital (1981). Patients with aphasia, patients with right hemisphere damage, and patients without neurological damage were asked to identify the symbol depicted in the correct context. Both impaired groups did significantly worse than the neurologically normal group. Wapner and Gardner also found a "continuum" of difficulty in the two groups of patients. Those with aphasia had greater difficulty with "relatively linguistic symbols," and patients with right-hemisphere damage had greater difficulty with "relatively nonlinguistic symbols." This finding suggested that PWA do have more difficulty with symbol identification than neurological normals, but supplementing linguistic information with pictures may increase recognition.

Wapner and Gardner used traffic signs among their stimuli. The authors did not address traffic signs in their discussion. However, a graph presenting their results showed that the participants with aphasia performed worse than the neurological normal group in matching the traffic sign to its correct scenario. However, the authors offered no specific information on the statistical significance of that finding. Considering that road signs contain both words and pictographic information of differing amounts, the extent to which pictures may supplement linguistic information in this category is still in question.

Difficulty interpreting symbols may be measured by more than just accuracy. While both studies show that PWA have difficulty correctly interpreting symbols, neither of these studies reports detailed measures of response time. Longer response time in responding to questions would equate to inefficient processing. Quick response time is especially important in a time sensitive activity like driving, where multiple decisions must be made both accurately and rapidly in order to maintain safety. Therefore, the time it takes a PWA to interpret a road sign's function should also be investigated.

Studies Examining Driving and Aphasia

Although driving is important to mental and physical health, few researchers have examined the effects of aphasia on driving ability. Many studies have examined driving post-stroke and have included participants with lesions that may result in aphasia. However, these studies (a) did not mention aphasia (Fisk et al. 2002; Devos et al. 2011; McKay et al., 2011); (b) actively excluded it (Lundqvist et al. 2000; Perrier et al. 2010); or, (c) did not specifically investigate it (Nouri et al 1987; Schanke and Sundet, 2000; Akinwuntan et al. 2002).

Considering the prevalence of aphasia following stroke, exclusion of language as a variable from these studies means that the current research has revealed only so much about this population's driving abilities.

While most stroke and driving studies have not investigated how post-stroke language impairment may affect driving, a few have included a measure of language and aphasia in their investigation with mixed results. Akinwuntan et al. (2002) used the presence or absence of aphasia as a variable in examining predictors of driving ability post-stroke. They found aphasia was not a significant factor. That study did not describe the method used to diagnose aphasia. Without that information, it is difficult to understand what the results mean. Schanke and Sundet (2000) and Nouri et al. (1987) opted to measure single, but different, language modalities in their studies on stroke survivors and driving ability. Schanke and Sundet used the "Similarities" subtest of the *Weschler Adult Intelligence Scale* (Weschler, 1997), to measure what they termed as "verbal function" (2000). Nouri et al. used the *Token Test Part V* (De Renzi & Vignolo, 1962) to measure auditory comprehension (1987). Nouri et al. found that auditory comprehension was predictive of driving performance but Schanke and Sundet found that verbal function was not (1987; 2000).

Despite the possibility that a reading impairment could impact driving performance, only four studies that examined the driving performance and focused on aphasia were found, and only one study was completed since 2000 (Hartje, Willmes, Pach, & Hannen, 1991; Lebrun, Leleux, Fery, Doms, & Buyssens, 1978; Mackenzie & Paton, 2003; Matsko, Boblitz, Glass, & Rosenthal, 1975). Two of these studies specifically investigated aphasia and road sign recognition (Lebrun, Leleux, Fery, Doms, & Buyssens, 1978; Mackenzie & Paton, 2003). Results from the studies that directly examined aphasia and driving have supported that presence of aphasia can impact driving (Hartje, Willmes, Pach, & Hannen, 1991; Mackenzie & Paton, 2003; Matsko, Boblitz, Glass, & Rosenthal, 1975).

Studies Examining Driving Performance and Aphasia

Matsko et al. (1975) compared PWA's performance on a communication scoring system to a simulated driving exercise. The driving simulator included urban, expressway, and intercity routes with participants scored on adequate signaling, steering, braking, speed, and accelerator control. They found that participants that did not have "functional communication skills" did not perform well in the simulator (Matsko et al., 1975). A detailed interpretation on the strengths and limitations of this study is difficult because access to the paper is limited. The paper was presented at the 1975 assembly of the American Academy of Physical Medicine and Rehabilitation and only the abstract can be obtained. Additionally, the study's abstract did not mention road sign compliance or even if road signs were used in the simulation. However, even if the reason for that deficit was not delineated in the available results, the results support that those with aphasia may have more difficulty driving.

Hartje et al. (1991) examined driving ability using both psychometric tests and an on-road driving test administered by a licensed driving instructor. Their participants were in-patients at a neurological rehabilitation center in Germany. Patients with seizures, hemianopia, double vision and uncontrolled diabetes mellitus were excluded, although other perceptual, motor, and cognitive impairments were not controlled for in either the aphasia or non-aphasia group. Hartje et al. reported that a significantly lower proportion of patients with aphasia passed the driving test than those in the group that had brain damage but no aphasia (42% to 72% respectively). They reported no relation between type of aphasia and driving ability. However, no patients with global aphasia, the most severe type of aphasia, passed the driving test.

While Hartje et al.'s analysis did not examine road signs specifically, their results implicate PWA's difficulty interpreting them. *Careful observation* and *following signposts* were behaviors that patients who failed the driving test had the most trouble performing. Hartje et al.'s results show PWA had a lower mean percent of "adequate actions" in *following signposts* as compared to those without aphasia. The mean percent of adequate actions for PWA who passed the driving test was 93.8 as compared to 100.0 in those without aphasia. The mean percent of adequate actions for PWA who failed the driving test was 76.5 as compared to 87.5 in those without aphasia. Difficulty in *following signposts* implicates road sign interpretation in poor driving performance specifically in PWA.

Hartje et al.'s study had limitations. While a standard protocol was used with all participants and was administered by someone experienced with driving instruction, these results are limited due to unknown inter- or intra-rater reliability. The authors did not exclude participants based on perceptual, motor, or cognitive deficits. Therefore, the participants with aphasia could have had additional perceptual, motor, or cognitive deficits that affect driving depending on the extent and severity of their injuries. While the authors showed that PWA did have poorer driving performance compared to others with brain damage, their reported data did not account for extraneous factors that could have affected driving.

Studies Examining Road Signs and Aphasia

Lebrun et al. (1978) specifically examined road sign recognition in PWA as compared to neurologically normal participants and those with cortical lesions but without language impairments. Participants were required to correctly respond to road markings and 20 different traffic signs using a miniature car on a model road. Their participants consisted of four people with Broca's aphasia, a disorder that primarily affects expressive language; two patients with right hemisphere lesions without aphasia; and five drivers without neurological symptoms. Out of a possible 19 correct answers, the PWA gave 5, 12, 10, and 4 correct answers; the right hemisphere patients gave 16 and 17 correct answers; and the normal group gave 19, 19, 18, and 17 correct answers. Lebrun et al. (1978) then repeated the study using a shorter version of the test with nine participants with aphasia and five participants with right hemisphere brain injury without aphasia. They again found results that indicated PWA have greater difficulty interpreting road signs. The participants with aphasia gave 16, 14, 14, 11, 10, 8, 8, 6, and 5 correct answers. The participants without aphasia gave 16, 15, 15, 15, and 12 correct answers. These results indicate that the participants with aphasia could perform as well or better than those without language impairments, but they also showed greater variability and lower range scores.

Lebrun et al.'s (1978) results show that even those with an aphasia type characterized by expressive, not receptive, deficits have difficulty interpreting road signs. That finding supports that due to the interconnectedness of the language system, any fault in the system may indicate difficulty with road signs regardless of modality. Lebrun et al.'s (1978) also investigated only accuracy, not response time. As stated previously, driving is a time-sensitive skill and safe driving requires not just making the right choice but doing so quickly.

Mackenzie and Paton (2003) most recently investigated aphasia and road sign recognition. Mackenzie and Paton's participants were PWA who had returned or desired to return to driving, and a group of neurologically normal participants who were matched with the participants with aphasia in age, educational background, and years of driving. They examined road sign identification through the (a) the Road Sign Recognition Test from the *Stroke Driver Screening Assessment* (*SDSA*) (Nouri & Lincoln, 1993), which requires the matching of road signs to appropriate situations in which they would be found; (b) auditory comprehension of Highway Code road sign descriptions; and (c) reading comprehension of Highway Code road sign descriptions. The authors reported that the PWA, even those that had returned to driving, had performed significantly worse than the control group. In the Road Sign Recognition Test, PWA took longer—7.61 (SD = 3.03) minutes on average compared to 4.94 (SD = 2.01) minutes; and were less accurate—identifying 8.11 signs (SD = 2.30) out of 12 compared to 10.72 (SD = 1.18). The PWA also scored significantly worse than the normal control group on the Highway Code road sign descriptions. On the auditory comprehension of road sign descriptions, PWA identified 9.53 signs (SD =2.58) out of 12 compared to 11.56 (SD = .62) identified by neurological normal control group. On the reading comprehension of road sign descriptions, PWA identified 9.12 signs (SD = 2.93) out of 12 compared to 11.61 (SD = .62) identified by neurologically normal control group. The poorer performance of the aphasia group supports that PWA have greater difficulty interpreting the linguistic information necessary to identify road signs.

Mackenzie and Paton's study of road sign recognition in PWA is valuable because it assesses both accuracy and timing, both important in on-road driving. Their findings are somewhat limited by the measures used. The authors use the Road Sign Recognition Test from the *Stroke Driver Screening Assessment*, which does not assess understanding of the road sign's function but requires matching it to the appropriate environment. The *SDSA* then may only assess road sign recognition as it is connected with memory, not function. Mackenzie and Paton's auditory and reading comprehension road sign tests required matching official, governmental descriptions to the road signs. Some descriptions do not include function. Research examining functional interpretation of road signs is needed.

Rationale for this Study

The literature supports a theoretical deficit in interpreting road signs through linguistic or related symbolic processes. Additionally, the studies that have examined aphasia and driving performance have underscored aphasia's negative effect on performance and road sign interpretation. However, the available literature regarding PWA and road sign recognition is limited. Few studies have examined road signs and aphasia. No studies have examined road sign interpretation accuracy and response time, which are both important characteristics in safe driving. This study will provide information on both the accuracy and response time of road sign interpretation in PWA as compared to those without aphasia.

Research Questions

This study will investigate the relationship of presence of aphasia to road sign interpretation abilities. The study will examine the differences between an aphasia group (AG) and a neurologically normal control group (CG) on measures of accuracy and response time. This study aims to answer the following questions:

1) Does presence of aphasia significantly affect road sign interpretation accuracy?
2) Does presence of aphasia significantly affect road sign interpretation response time?

Research Hypotheses

Based on current literature and the theoretical underpinnings of aphasia's effect on road sign recognition, I have developed the following hypotheses:

1) The AG will be less accurate in the road sign experiment than the neurological normal CG.
2) The AG will show significantly longer response times in the road sign experiment than the neurological normal CG.

METHODS

Design

This was a prospective, between-group study used data collected from a larger study by Donovan, Savage, Varnado, & Brown (2014). This study aimed to determine if aphasia had an effect on the accuracy and response of road sign interpretation using a sample of 10 adults with aphasia and 10 adults who are neurologically normal. This study was approved by the Louisiana State University Institutional Review Board as part the larger study. Informed consent was obtained prior to data collection.

Participants

The participants were (a) 10 community-dwelling people without self-reported history of neurological disorder and (b) 10 community-dwelling people who had sustained stroke in the left hemisphere and had received a diagnosis of aphasia ≥ 6 months prior to study participation. They must have returned to driving or have stated a desire to return to driving. They were between 50-85 years of age. The participants were native English speakers with ≥ 8th grade education.

Sampling Procedures

Participants were recruited from the Louisiana State University-Speech, Language, Hearing Clinic (LSU-SLHC), community stroke support groups, word of mouth, and the Communication Outcomes Research Laboratory (COR Lab) participant database. Exclusion criteria for both groups included other neurologic or language deficits; history of sustained or unresolved drug and alcohol abuse or mental illness; failed aided or unaided hearing screening; legally blind, visual field blindness, color blindness, left neglect; and motoric deficits that make them unable to use a computer keyboard.

To determine their eligibility for the study, participants completed a two-part screening process. First, a research assistant conducted a telephone screening to determine preliminary inclusion or exclusion characteristics including age, native language, community dwelling status, current driving status, and basic pertinent medical history. Presence of aphasia was confirmed during telephone interview based on self-reported medical history and as determined by research assistant with experience in communication disorders.

Participants who met these criteria were then additionally screened the day of the experiment. Participants needed to have aided or unaided hearing ability that allowed them to follow directions. Vision was screened using the Rosenbaum vision screening (Rosenbaum, 1982) and a color blindness screening (Ishihara, 1917). Adequate visual field was assessed by having the participant indicate the four corners of the computer screen. The presence of aphasia was confirmed based on scores between 5.5 and 9 in any language domain on the *Aphasia Language Performance Scales* (*ALPS*; Keenan & Brassell, 1975).

Sample Demographics

Participants ranged from 50 to 84 years old. Groups were closely matched in mean age (CG *M* = 66.2, AG *M* = 66.1) although the AG had greater variability (CG *SD* = 4.94 years, AG *SD* = 10.90 years). The CG also displayed greater variability in gender of participants. The CG consisted of 4 females and 6 males. The AG consisted of 1 female and 9 males. In both groups, education levels ranged from completion of high school to completion of advanced degrees. The AG presented with more instances of completed college degrees (n = 4) and advanced degrees (n = 4) than the CG (college degrees = 3, advanced degrees = 3). Participant demographic information is displayed in Table 1.

Table 1. Participant Demographics

Group	ID #	Age (years)	Sex	Education Level
Control	101	60	F	Some College
Control	102	74	F	High School
Control	103	64	M	Advanced Degree
Control	104	70	F	College Degree
Control	105	61	M	College Degree
Control	106	69	M	Advanced Degree
Control	107	64	F	Advanced Degree
Control	108	72	M	Some College
Control	109	67	M	College Degree
Control	110	61	M	Some College
CG *M* age = 66.2 years (*SD* = 4.94 years)				
Aphasia	301	84	M	College Degree
Aphasia	302	77	M	College Degree
Aphasia	303	54	M	Advanced Degree
Aphasia	304	66	M	Advanced Degree
Aphasia	305	68	M	Advanced Degree
Aphasia	306	67	M	College Degree
Aphasia	307	70	M	Advanced Degree
Aphasia	308	50	M	High School
Aphasia	309	53	M	College Degree
Aphasia	310	71	F	Some College
AG *M* age = 66.1 years (*SD* = 10.90 years)				

Materials

Overview

Participants were presented with a road sign interpretation experiment on a laptop computer using in *E-Prime 2.0* software.

Road Sign Stimuli

Road sign images were found using Google Image search. In order to validate the road signs for use in the experiment, five individuals aged 50-85 years old with no known linguistic or cognitive disorders from southern Louisiana were asked if they had previously seen the signs. Thirty-six road signs were recognized by the majority of the individuals surveyed and were used in the experiment. Three signs were used in the practice portion of the road sign interpretation experiment and 33 signs were used for data collection. Researchers wrote the possible road sign interpretations for each image using simple vocabulary and syntax in order to facilitate understanding by the AG. The written stimuli for the experiment and selected road signs are presented in Appendix A.

E-Prime 2

E-Prime 2.0 is a software suite of applications used to design and run experiments on computers (Psychology Software Tools, Pittsburgh, PA). The *E-Prime 2.0* suite collects precise data on a number of variables based on the experimental design. This study's experiment was designed to present road sign stimuli and record the accuracy and speed of each participant's response. The experiment was presented on a Dell Latitude E5540 laptop computer. The 7, 4, and 1 keys on the number pad of the laptop were marked respectively with red, green and blue colored stickers. The stickers corresponded to the color of the text choices presented on the laptop screen during the experiment. The set-up is presented in Figure 2.


Figure 2 Road Sign Experiment Set-up

Procedures

The participant chose the date and time of data collection. Informed consent was received before the experiment began (See Appendix B). A research assistant performed screening procedures and the experiment in an area with minimum distractions, i.e. in a Louisiana State University Speech, Language, Hearing Clinic (LSU-SLHC) treatment room, a conference room at a local hospital, or in the participant's home.

The participant sat in front of the laptop computer with a 16-inch LED screen. All text presented on the laptop screen was written in Times New Roman font size 18, which made individual letter height approximately 4.8 mm. Directions for tasks were spoken and provided in text on the computer screen. The participant's completed three tasks using the laptop experiment: (a) a simple response time assessment, (b) practice for the road sign experiment, and (c) the road sign experiment. For the practice session and road sign experiment, the participant was asked to answer the stimulus question, "What should a driver do if he sees this sign?" During practice, the research assistant sat next to the participant and clarified the experiment procedures. During the road sign experiment, the research did not answer questions, but could repeat the stimulus question and offer verbal encouragement.

First, the participant's simple response time was measured. The participant was asked to press the space bar when the screen changed to red. The screen changed from white to red at 3 randomly timed intervals.

The participant was then asked to practice the road sign experiment. The following was spoken and presented as on-screen text:

> You will see a series of road signs and then be asked to respond to what should a driver do when he sees this type of sign. On each of the following road signs, press the key that matches the color of the correct response. The screen will change to gray when you can respond. For each picture answer: "What should a driver do if he sees this sign?" Let's Practice. Press any key to start.

The screen randomly presented a road sign picture as well as three possible choices for action associated with the road sign, one correct and two foils (Figure 3; all possible responses are presented in Appendix A). Each choice was presented as red, green, or blue text, which corresponded with a colored laptop key. The three choices were also read aloud using a pre-recorded voice.

Figure 3 Road Sign Presentation

Choices were read at a slow rate to accommodate any language processing deficits in the participants with aphasia. The screen changed to gray after the three choices were read to signal to the participant that he could respond. After the response, the laptop displayed feedback if the response was correct or incorrect. If the response was incorrect, the research assistant would remind the participant of the instructions and that this was practice. The participant received four opportunities to practice before the experiment began.

After practice was completed, the experiment trial began. New instructions appeared on the screen and were read aloud to the participant. They were as follows:

> The experiment is going to start now. On each of the following road signs, press the key that matches the color of the correct response. The screen will change to gray when you can respond. There will be no feedback between slides and no questions during this part of the session. Do you have any questions or need to use the restroom now? The experiment will take about 20 minutes.

The research assistant allowed for questions and breaks at this time. Once questions or breaks were completed, the research assistant spoke and presented the following text,

> Ready? Remember, answer: "What should a driver do if he sees this sign?" Press any key to start.

The experiment began when the participant pressed the key. To decrease the possibility of anxiety, the research assistant moved from sitting beside to across from the participant, where they could not view the participant's choices. The stimuli were randomly presented exactly as they were in practice, but without feedback. The research assistant did not answer questions posed during this part of the experiment. If the participant had comments or feedback, the research assistant encouraged the participant to respond to "What should a driver do if he sees this sign?" or to "do their best." The software collected the accuracy and response time to each road sign presented. When finished, "The End" appeared on the screen. The research assistant thanked the participant and pressed the space bar to end the experiment. The experiment closed and the data were saved automatically on a flash drive attached to the laptop computer.

Data Analysis Plan

A between subjects MANOVA was conducted in SPSS v.22 to compare the effect of the presence of aphasia on accuracy and response time in a road sign interpretation experiment. Results were calculated with α set at .05. Response times that fell outside three standard deviations from the mean response time, i.e. outliers, were trimmed from the data set according to standard procedures (B. Barker, personal communication, March 2, 2015). Visual analysis of the data was performed to assess error/response patterns.

RESULTS

Data Analysis

This study aimed to answer the following experimental questions:

1. Does the presence of aphasia significantly affect road sign interpretation accuracy?
2. Does the presence of aphasia significantly affect road sign interpretation response time?

Mean number correct and response time were calculated for the CG and the AG. Standard deviations for mean number correct and response time were calculated for the CG and the AG. A between subjects MANOVA was conducted in SPSS v.22 to compare the effect of the presence of aphasia on accuracy and response time in a road sign interpretation experiment. An item-by-item visual inspection of number correct and response times per road sign was conducted to investigate possible trends in responses to specific stimuli.

Descriptive Statistics

The mean accuracy, mean response time, and standard deviations for these measures were calculated for each group based on their performance in the road sign experiment. Thirty-three items were presented for interpretation during the experiment. Therefore, the highest achievable number correct was 33. Response time was recorded in milliseconds. All measurements were rounded to two decimal places.

Mean Number Correct. *M* number correct was calculated for each group by dividing the sum of the group's number correct by the total number of participants in that group. Results indicated CG *M* = 32.30, (*SD* = 1.06, range 30 - 33). *M* number correct for the AG was 28.60 (*SD* = 2.76, range 24 - 33). Summary of the *M* accuracy data is presented in Figure 4 and Table 2.

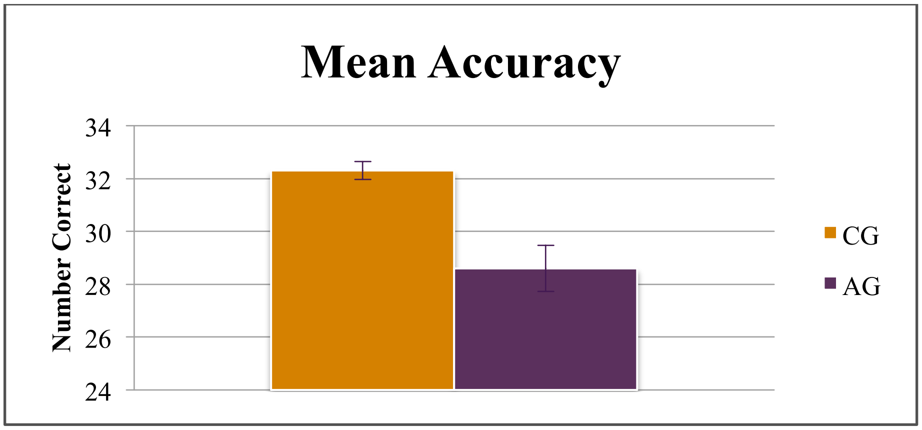

Figure 4. Summary of Mean Accuracy Results

Table 2. Accuracy Per Participant

CG		AG	
Participant Number	Number Correct	Participant Number	Number Correct
101	33	301	29
102	33	302	27
103	33	303	30
104	33	304	33
105	32	305	32
106	33	306	30
107	32	307	27
108	31	308	28
109	30	309	24
110	33	310	26
M = 32.3 (*SD* = 1.06)		*M* = 28.60 (*SD* = 2.76)	

Mean Response Time. Response time was measured in milliseconds (ms). Response times to single road sign stimuli that were greater than or equal to 3 standard deviations from the mean were deemed outliers and were eliminated from the data set. For the AG, 7 out of 330 response times were eliminated from analysis. After trimming the data, the *M* response time for the AG was 2777.62 ms (*SD* = 2144.92 ms, range 434.27 ms - 6967.33 ms). For the CG, 4 out of 330 response times were eliminated from analysis. After trimming the data, the *M* response time for the CG was 1211.58 ms (*SD* = 390.66 ms, range 921.24 ms - 2000.12 ms) Summary of the *M* response time data is presented in Figure 5 and Table 3.

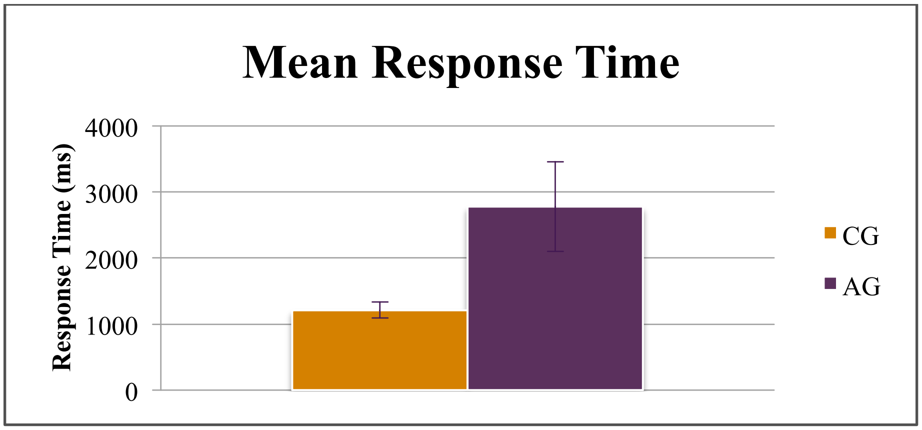

Figure 5. Summary of Mean Response Time Results

Table 3. Mean ResponseTime Per Participant

CG		AG	
Participant Number	Mean Reaction Time per stimulus (ms)	Participant Number	Mean Reaction Time per stimulus (ms)
101	927.97	301	3046.12
102	995.58	302	1852.70
103	2000.12	303	6967.33
104	1300.24	304	817.63
105	1343.30	305	1244.85
106	586.27	306	434.27
107	1560.24	307	5239.67
108	921.24	308	2097.49
109	1219.15	309	1524.36
110	1261.67	310	4551.79
M = 1211.58 (*SD* = 390.66)		*M* = 2777.62 (*SD* = 2144.92)	

Testing Statistical Assumptions

In order to determine whether the data met the assumptions of normality necessary for multivariate analysis, a Shapiro–Wilk test was conducted for each dependent variable ($\alpha = .05$). The results for response time, as measured in response time, were not significant and were found to have a normal distribution in both the AG (W = .901, $p = .225$) and the CG (W = .962, $p = .808$). The results for accuracy, as measured by number correct, were mixed. The results for the AG were not significant and found to have a normal distribution (W = .980, $p = .967$). The results for the CG were significant and therefore not normally distributed (W = .730, $p = .002$). The MANOVA was run using the Pillai-Bartlett trace because it is robust to violations of multivariate normality (Bray & Maxwell, 1985). A summary of Shapiro-Wilk results is presented in Table 4.

Table 4. Summary of Shapiro-Wilk Results

Dependent Variable	Group	Statistic	df	Sig.
M Response Time	AG	.901	10	.225
	CG	.962	10	.808
M Number Correct	AG	.980	10	.967
	CG	.730	10	.002*

*The mean difference is significant at the .05 level.

Using Pillai's trace, presence of aphasia showed a significant effect on mean number correct and response time, V=.996, F(2, 17) = 8.446, $p = .003$. A summary of Pillai-Bartlett trace results is presented in Table 5. Two separate univariate ANOVAs were then conducted to determine aphasia's effect on each of the dependent variables ($\alpha = .05$). The presence of aphasia showed a significant effect on *M* number correct, F(1, 18) = 15.696, $p = .001$. The AG was less accurate (*M* = 28.60, *SD* = 2.76) than the CG (*M* = 28.60, *SD* = 1.06). The presence of aphasia showed a significant effect on *M* response time, F(1, 18) = 5.160, p =.036. The AG was slower (*M* = 2777.62 ms, *SD* = 2144.92 ms) than the CG (M = 1211.58 ms, *SD* = 390.66 ms). A summary of univariate ANOVA results is presented in Table 6.

Table 5. Summary of Pillai-Bartlett Trace Results

	Value	F	Hypothesis df	Error df	Sig.
Pillai-Bartlett Trace	.498	8.446	2	17	.003*

*The mean difference is significant at the .05 level.

Table 6. Summary of Univariate ANOVA results

	df	Mean Square	F	Sig.
Mean Number Correct	1	68.450	15.696	.001*
Mean Response Time	1	12262444.37	5.160	.036*

*The mean difference is significant at the .05 level.

Item Analysis

A visual inspection of the raw data was conducted in order to identify patterns of accuracy and response time among the participants in their respective groups and as a whole. While descriptive and statistical measures demonstrated the AG was slower and less accurate in the road sign experiment, further information may be gleaned about the testing measures and the nature of the poor performance through visual inspection. Data are presented in Table 4 and 5.

Error/Response Pattern Analysis by Sign. Several patterns emerged during visual inspection of the accuracy data. The sign that was most poorly interpreted by both groups was the *Arrow Curve*, which was accurately interpreted by 12 of 20 (60%) of the entire sample. With this one exception, the group error patterns differed. After *Arrow Curve*, the three signs missed most by the AG were *Road Closed Ahead*, *Change in Speed Limit*, and *Road Curves*. After *Arrow Curve*, the three signs missed most by the CG were *Lane Ends*, *Left Only*, and *Curve Left*. Signs that showed the greatest difference of number of accurate interpretation between groups were *Road Closed Ahead* (AG = 40%, CG = 100%), *Change in Speed Limit* (AG = 60%, CG = 100%), *Road Curves* (AG = 60%, CG = 100%), and *Yield Sign Ahead* (AG = 70%, CG = 100%). Trends in accuracy by sign are present in Figure 6. Raw data for accuracy by sign are presented in Appendix C.

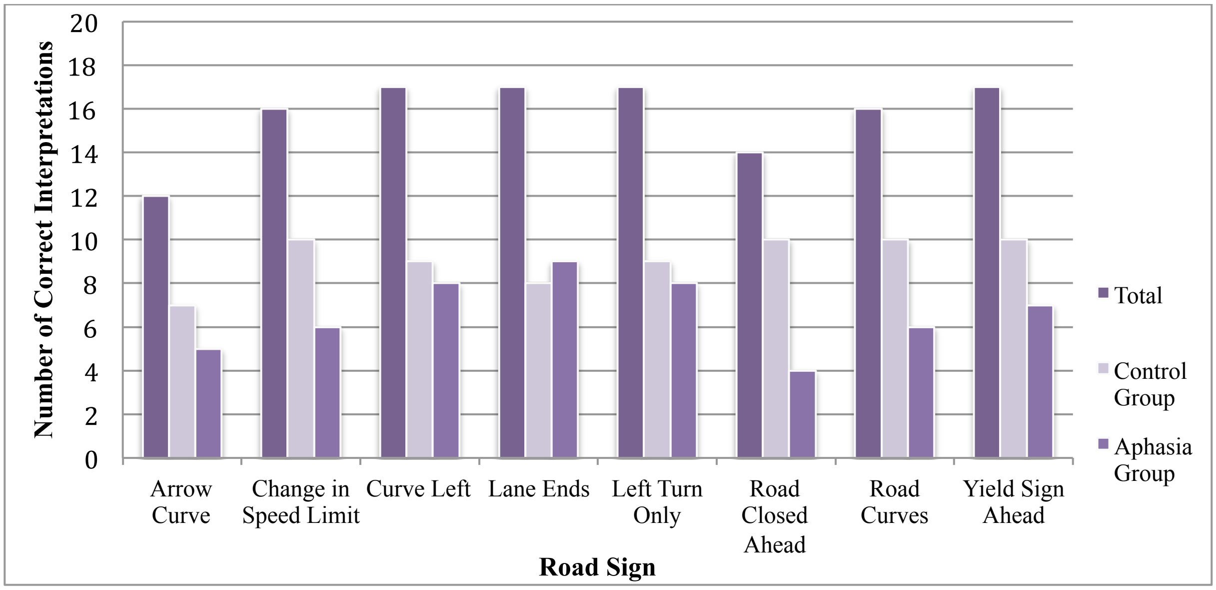

Figure 6. Summary of Accuracy Trends by Sign

Response Time By Sign. Several patterns emerged during visual inspection of the response time data. The signs that had the longest response time overall were *Change in Speed Limit* (*M* = 3924.789 ms), *No U-Turn* (*M* = 2892.55 ms), and *No Right Turn* (*M* = 2644.55 ms). The signs that had the shortest response time overall were *Watch for Bicyclists* (*M* = 1124 ms), *Stoplight Ahead* (*M* = 1259.5ms), and *Lane Splits Left and Straight* (*M* = 1281.55 ms).

However, the groups differed on their respective response time patterns. For the AG, the three signs with the longest response time were *Change in Speed Limit Ahead* (*M* = 6881.00 ms), *Lane Ends* (*M* = 3982.40 ms), and *Arrow Curve* (*M* = 3320.22 ms). For the CG, the three signs with the longest response time were *No U-Turn* (*M* = 3399.60 ms), *Curve Left* (*M* = 1452.30 ms), and *Yield Sign Ahead* (*M* = 1422.40 ms). For the AG, the three signs with the shortest response time were *Watch for Bicyclists* (*M* = 1399.30 ms), *Lane Splits Left and Straight* (M = 1453.80

ms), and *U-Turn* (*M* = 1511.50 ms). For the CG, the three signs with the shortest response time were *Stoplight Ahead* (*M* = 655.00 ms), *Watch for Bicyclists* (*M* = 848.7 ms), and *School Zone* (*M* = 883.1 ms). These patterns in response time by sign are presented in Figure 7.

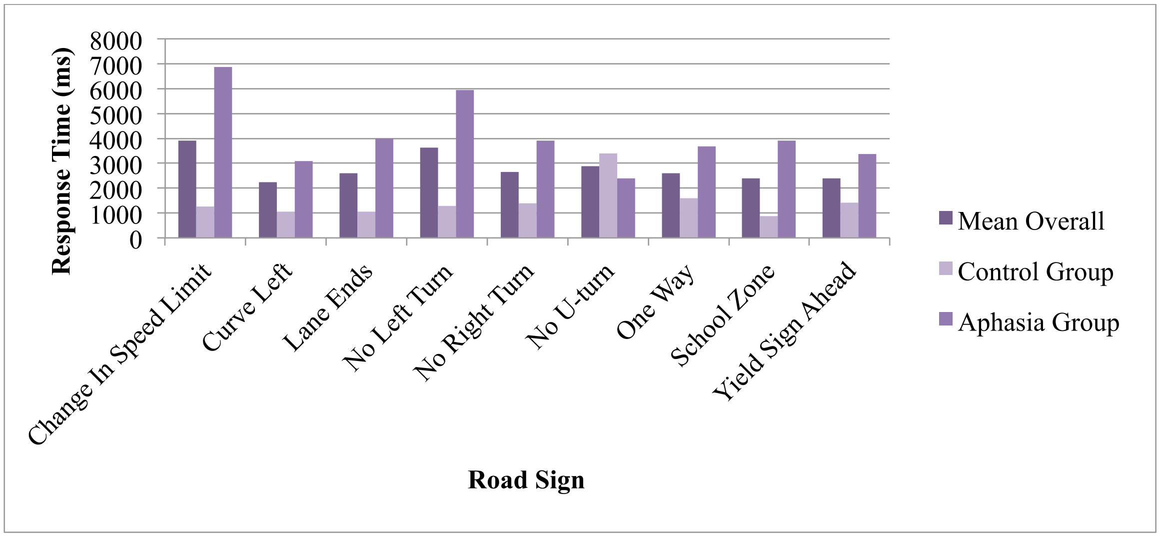

Figure 7. Patterns in Response Time by Sign

Signs that showed the greatest difference in response time between groups were *Change in Speed Limit* (Difference = 5616.8 ms), *No Left Turn* (Difference = 4666.7 ms), *School Zone* (Difference = 3020.70 ms), and *Lane Ends* (Difference = 2914.4 ms). These differences in response time by sign are presented in Figure 8. Raw data for response time by sign is presented in Appendix D.

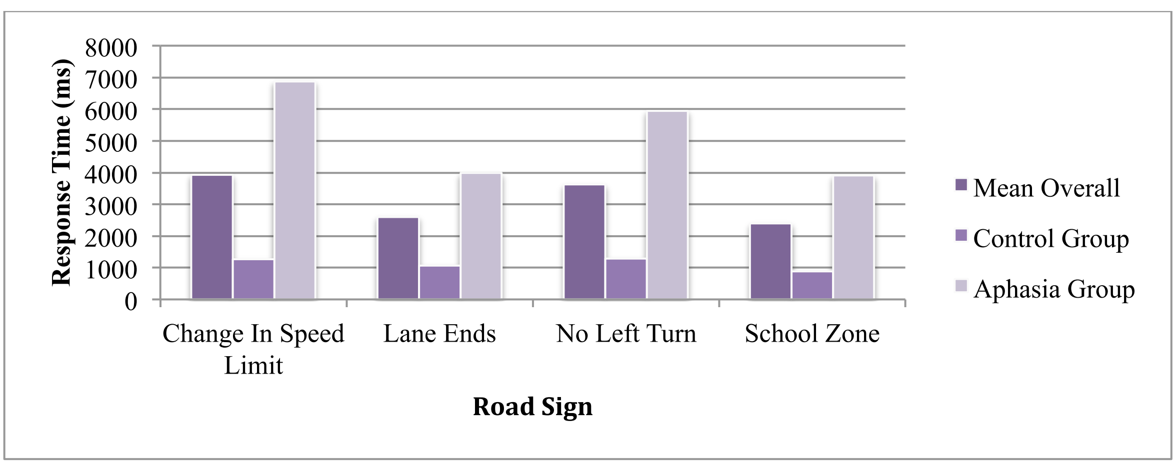

Figure 8. Greatest Differences in Response Time by Sign

DISCUSSION

This study aimed to determine if aphasia has an effect on the accuracy and response time of road sign interpretation using a road sign interpretation experiment presented on a laptop computer. The results supported findings from previous studies, but also added new information indicating the need for further investigation into road sign interpretation in PWA.

Summary of Results

The study results demonstrated that aphasia negatively impacted accuracy and response time in the road sign interpretation experiment. Statistically significant differences in performance between groups on both of these measures were found; the AG was less accurate and slower than the CG. The following sections will discuss the findings based on the two initially posed research questions, their respective hypotheses, and the relationship to the previous literature investigating aphasia and driving.

Question One

The purpose of question one was to determine if aphasia significantly affected road sign interpretation accuracy as measured by number of correct responses in a road sign experiment. The investigator hypothesized that the AG would be less accurate in the road sign experiment than the neurologically normal CG. Findings demonstrated that the AG was significantly less accurate than the neurologically normal CG.

The present study's results are consistent with Mackenzie and Paton's who reported that their participants with aphasia performed less accurately on the *SDSA* road sign test than a neurologically normal group (2003). However, the *SDSA* requires participants to match a sign to a pictured scenario, but does not assess interpretation of a sign's meaning, as the current study did. Therefore, while the *SDSA* road sign test appeared to be sensitive to road sign recognition as it pertained to memory, it did not provide any data to demonstrate that participants understood what to do when they saw a road sign (i.e. interpret the road sign), which would pertain more to language or symbol processing. The present study's results support Mackenzie and Paton's findings that there were differences between people with and without aphasia in road sign recognition. More than that, the present study also indicates that road sign *interpretation* is significantly different between people with and without aphasia.

In contrast to Mackenzie and Paton's study, Lebrun et al. (1978) did use an assessment of road sign interpretation. Similar to the present study, their results demonstrated that PWA were less accurate than those without aphasia (Lebrun et al., 1978). Additionally, Lebrun et al. (1978) demonstrated that poor road sign interpretation was found in participants with different types of aphasia, not just those with comprehension deficits. The researchers found that even those with aphasia characterized by expressive language deficits had difficulties with road sign interpretation. The results of the present study also include participants with different types and severities of aphasia. And as with Lebrun et al. (1978), the present study found that the AG was significantly less accurate than the CG and had greater variability in accuracy scores.

Question Two

The purpose of question two was to determine if aphasia significantly affected road sign interpretation response time on a road sign experiment. The present study's hypothesis was that the AG would have significantly longer response times in the road sign experiment than the neurological normal CG. Findings demonstrated that the AG was significantly slower in interpreting road signs than the CG.

Response time is important for road sign interpretation as quick, accurate responses are needed for safe driving. Despite this, there was only a single study that directly investigated speed of response (Mackenzie & Paton, 2003). The present study's results support their findings. Mackenzie and Paton found that PWA took greater time to respond on the road sign recognition test in the *SDSA* than neurologically normal people. The present study also found the AG had greater response times to road sign stimuli than the CG. As mentioned previously, the *SDSA* is not a test of road sign interpretation per se but more a test of road sign recognition. On the other hand, Lebrun et al. did use a measure of road sign interpretation, but did not investigate speed of processing (1978). Therefore, the present study builds on their results by providing a measure of interpretation and showing that PWA were not only less accurate, but also slower in interpreting road signs. Further discussion of the differences between the group's interpretations of road signs in both accuracy and response time follows.

Item Analysis

An item-by-item visual inspection of number correct and response times per road sign was conducted to investigate possible trends in responses to specific stimuli. Trends were found in the different groups that may support the idea that damaged language and symbolic processing could be responsible for the AG's poorer performance on the road sign interpretation experiment. The accuracy data appears easier to interpret then the response time data, possibly due to a more complex relationship between processing time and road sign. Additional investigation will ultimately clarify the relationship between response time and road sign interpretation.

Overall, *Arrow Curve* was the most missed sign across both groups. The high incidence of misinterpretation in the CG suggests that this may actually be a difficult stimulus to interpret for older adults with and without aphasia. While the *Arrow Curve* was approved during our initial study of the face validity of the signs, it may have been less familiar to participants. The examiner noted the sign often drew unsolicited comments from the participants that they "did not know" or even "had never seen" this sign before. The *Arrow Curve* rarely occurs in isolation as it was presented in the present experiment and usually marks steep curves that could keep it out of a driver's direct line of sight. While this sign's high incidence of error may signify a poor stimulus choice, other signs that were difficult for the AG did not have error patterns suggesting methodology issues.

The AG's error pattern gives stronger evidence for the mechanism of interpretation difficulties. After the *Arrow Curve* sign, there was a clear difference between the groups as to which signs were the least often accurately interpreted. It is notable that the sign that had the largest difference in accuracy between groups was *Road Closed Ahead*. This was also one of three signs that only used text with no ancillary symbols to direct the interpreter. These signs are linguistically dense by comparison to other road signs. The other two linguistically dense signs, *Speed Bump Ahead* and *Speed Limit*, had answers that contained their text (Do not go over 55 miles per hour; Slow down to go over the bump.) that may have made the correct choice easier to identify. The error pattern for *Road Closed Ahead* supports that language processing deficits may be a cause for misinterpretation.

Change in Speed Limit and *Yield Sign Ahead* were two signs that also large differences between groups. Although *Change in Speed Limit* and *Yield Sign Ahead* could not be labeled linguistically dense as *Road Closed Ahead* could be, these two signs included a combination of different symbols, which could be considered more symbolically complex then other road sign stimuli presented. This finding is consistent with the argument asserted in the literature review that road signs may be subject to interpretation deficits because they make up an invented symbol system.

Understanding the relationship of sign to response time was murkier than sign to accuracy and may imply a more complex relationship of response time to road sign interpretation. *Change in Speed Limit* had the longest mean response time in the AG and also showed the greatest response time difference between groups. These data may support the notion that the sign's increased symbolic complexity increased processing time for PWA. However, there are few obvious examples to support this idea. Some signs with long reaction times were also interpreted accurately less often, e.g. *Arrow Curve* or *Change in Speed Limit Ahead*, implying slower, less accurate processing. Signs with high accuracy and short response time that also included simple, highly-identifiable symbols, e.g. *Watch for Bicyclists*, also support that response time may represent processing speed because these signs would be easier to process. However, others did not clearly show this trend, e.g. *Lane Ends*, which had long response time but good accuracy in the AG. There were no incidences of short response time with more inaccurate interpretations, which implies that participants were not responding impulsively to the stimuli. Other than these preliminary findings though, visual inspection of the response time data was not sufficient to find substantial patterns. Further analysis of patterns in response time, perhaps by statistical measures, is needed.

Clinical Implications

The role of healthcare providers, including speech-language pathologists, in advising PWA about return to driving is not well-documented in law or literature. There are no federal laws addressing minimum criteria for return to driving after stroke. Often times the primary physician or an occupational therapist provides advice on return to driving, which is logical when there are motor impairments associated with the stroke (ASA, 2013). However, the present study suggests aphasia may have an effect on driving and therefore, speech-language pathologists may serve an important role in helping PWA make informed choices about return to driving. While current information is too limited to make recommendations, future research may determine the extent and scope of that future role, which could range from advice to assessment.

While there is evidence that stroke survivors do not solicit advice even from doctors (Fisk, Owsley, & Pulley, 1997), speech-language pathologists may contribute most through patient education, which can be a powerful with older adults. Sources suggest older adults and the stroke population will often regulate their driving habits based on their perceived deficits (Donorfio, Mohyde, Coughlin, & D'Ambrosio, 2008; Finestone et al. 2010). However, this self-regulation is predicated on knowledge of their impairment. It is possible that education by a speech-language pathologist or other healthcare professional of the difficulties aphasia may cause on road sign may actually activate that self-regulating behavior. This idea may actually be the impetus for further research into aphasia and driving. If self-awareness leads to self-regulation then educating adults with aphasia may be key to creating safe roadways.

Limitations

This study involved a small convenience sample, which limits the study's generalizability. The sample was small for each group, increasing the possibility that they may not accurately represent the population. Also, it was difficult to recruit participants into the AG. Therefore, the participants may represent unique characteristics of people who "volunteer for research studies" that are not present in those who do not volunteer. While we were able to age match, the groups differed in education level and gender. As such, results may be limited in application due to these demographics as well.

Limitations arose with the road sign interpretation experiment itself. The design of the experiment required the use of language (text and audio) to assess the differences between groups with and without language impairment. Because of this, a difference between groups was expected just as reflection of different language ability. However, precautions were taken to decrease the effect of this limitation: (a) response choices were presented in more than one language modality; (b) choices were short and used simple grammar and vocabulary; (c) choices were presented at a slower speaking rate by an "aphasia-friendly" speaker who was familiar with the population; (d) response foils were randomly chosen in order to decrease the likelihood of specific confusing combinations; and (e) participants in both groups could only respond after all choices on the screen were read aloud, thereby giving the participants in the AG greater time to process the language of the experiment. The experimental measures could be changed in future research to address this concern.

Future Research

Now that preliminary finds suggest aphasia does have an effect on road sign interpretation, future research should focus on further comparison of aphasia characterization to road sign deficits, and comparison of different driving performance measures.

A comparison of language deficits to road sign interpretation skills is needed. The present study does not offer enough information to say the type of language deficits most likely to cause problems or the level of severity at which the person with aphasia would be safe to drive. The level of variability in the AG suggests that such a profile would be important in order to create clinical standards for use by speech-language pathologists.

The limitation associated with use of language in assessment highlights the need for dynamic performance measures in addition to this type of static assessment. An experiment that included on-road or driving simulator trials would allow researchers to assess road sign interpretation directly, without the use of language, and for comparing those results to a static assessment of road sign knowledge. Such performance measures could provide information on the extent that road sign understanding applies to actual driving ability, which at this time is also unclear.

Conclusion

This study has established preliminary evidence to support that PWA have difficulties interpreting road signs both in measures of accuracy and response time, both qualities that are needed for safe driving. The results support previous findings in Mackenzie & Paton (2003) and Lebrun et al. (1978) that also showed PWA have poorer road sign recognition skills than those without aphasia. Moreover, this study presents new evidence that PWA may have difficulty with accurate and efficient road sign interpretation as opposed to simply recognition. Considering the prevalence of aphasia and the significance of driving to older adults, these results may provide important information to health professionals who are asked to advise a PWA who wishes to return to driving after stroke. More study, however, is needed to investigate the profile of deficits that contribute to poor road sign interpretation and to build upon and support the present study's results.

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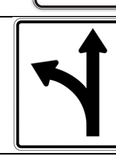
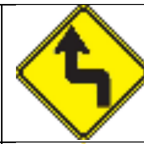
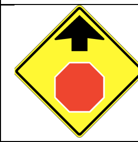
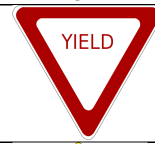
APPENDIX A: ROAD SIGN STIMULI

Sign	Correct Response	Practice	
Yield	Slow down and watch for other cars.	Practice	
Stop	Come to a complete stop.	Practice	
Parking	Park here.	Practice	
Stop Light Ahead	Prepare for a traffic light ahead.		
One Way	Do not go right.		
Slippery Road	Slow down, the road may be slippery.		
No U-Turn	Do not make a U-turn.		
No Left Turn	Do not turn left.		
No Right Turn	Do not turn right.		
Left Only	Get in this lane to turn left.		
Lane Splits (Left and Straight)	Get in this lane to go straight or turn left.		

Road Curves	Curve with the road.		
Curve Left	Curve left.		
Arrow Curve	Use caution curving.		
Curve Right	Curve right.		
Four Way Stop	Prepare for a four way intersection ahead.		
Road Closed Ahead	Find a different route.		
Speed Limit	Do not go over 55 miles per hour.		
Railroad Crossing	Watch out for trains.		
Road Work Ahead	Be alert to road worker.		
Median (Go Right)	Stay to the right of the median.		
Pedestrian Crossing	Stop for pedestrian.		
Flagman Ahead	Follow the road workers directions.		

Lane Ends	Merge left when lane ends.		
Stop Sign Ahead	Prepare to stop ahead.		
Yield Sign Ahead	Prepare to yield ahead.		
Change in Speed Limit	Prepare to change speed ahead.		
Median (Divided Highway)	Stay on own side of median.		
Watch for Bicyclists	Be cautious of bike riders.		
Speed Bump	Slow down to go over the bump.		
Evacuation Route	Follow the signs to safety.		
No Parking	Do not park here.		
Handicap Parking	Park here if handicap.		
U-Turn	Make a u-turn if needed.		
Do Not Enter	Do not go this way.		

School Zone	Watch for children.		

APPENDIX B: INFORMED CONSENT

P.I.: Neila Donovan, Ph.D., CCC-SLP
Project Title: Road sign recognition during computer testing versus driving simulator performance for healthy, stroke, and stroke + aphasia groups

D. Informed Consent Form

Consent Form

Project Title: Road sign recognition during computer testing versus driving simulator performance for healthy, stroke, and stroke + aphasia groups

Performance Site: LSU Speech-Language and Hearing Clinic; LSU Gulf Coast Center for Evacuation and Transportation Resiliency

Investigators: The following investigators are available for questions, Monday-Friday 8:00 a.m.-4:30 p.m.

Chantelle B. Varnado, M.S. CCC-SLP	Neila Donovan, Ph.D., CCC-SLP
Department of Communication Disorders, LSU	Department of Communication Disorders, LSU
(225)405-8627	(225)578-3938

Purpose of the Study: We want to know if people perform differently on computer-based road sign tasks versus driving simulator tasks.

Inclusion Criteria: good hearing and vision, drives or wishes to return to driving, no other neurologic or language deficits, no history of sustained or unresolved drug/alcohol abuse or mental illness, no history of motion sickness, native English speaker, 8th grade education or more, 50-85 years old, able to get in and out of the car with someone standing by, steer the simulator, move foot between the gas and brake, adequate cognition to perform tasks. STROKE GROUP: greater than 6 months after stroke, left/right/subcortical stroke. APHASIA GROUP: confirmed using testing.

Exclusion Criteria: brainstem strokes, transient ischemic attacks, subdural hematomas, subarachnoid hemorrhages, traumatic brain injury, less than 6 months after stroke, legally blind, visual field blindness, color blindness, left neglect, impaired depth perception, unable to reduce motion sickness after 3 simulator trials.

Description of the Study: To pass the screening to be in the study we will ask you to complete some tests, questionnaires, or other tasks to be sure you qualify for the study. We will use some other questionnaires so we can describe each group's makeup. The screening should take no more than one hour for the control group and the stroke group. It may take about two hours for the people with aphasia because they have to take one additional test.

The study includes two experiments. In experiment 1, we will ask you to identify road signs on a computer. We expect this experiment to take about one hour at the most. In experiment 2, we will ask you to do three driving scenarios in a driving simulator. The driving simulator is a fully equipped car just like the ones we drive on the streets. We expect this experiment to take about one hour at the most.

Benefits: You will not be paid to be in this study. We do not pay you for this study. You are helping us learn more the effect of stroke and stroke + aphasia on driving performance and road sign recognition.

IRB #3493 Approved May 30, 2014 through May 29, 2015

Risks: The only known risk is possible motion sickness in the driving simulator. If you are unable to overcome motion sickness after three trials, you will be excused excluded from the study. The driving simulator is also equipped with a STOP button that you can push anytime during Experiment 2 if you begin to feel ill or want to stop for any other reason.

Right to Refuse: This is a volunteer study. You do not have to be in it. If you decide that you do not want to be in the study, you can say no or stop the study at any time. Your decision to stop being in the study will not affect your ability to participate in other studies or in therapy at the LSU Speech-Language-Hearing Clinic.

Privacy: We will protect your privacy. We replace names with secret codes. Only my research helpers and I know the codes. We will keep everything double-locked. We also use a special password to get in our computer. We never use any information that could identify you if we write about this study.

Financial Information: There is no cost for participation in this study, and you will not be paid for participation in this study.

Thank you for your participation!

If you have any questions about the study, you can ask the investigators at any time.

Signatures:

The researcher discussed the study with me. She answered all of my questions. I understand that if I have any other questions, I can call the researchers, Chantelle Varnado or Dr. Neila Donovan. I understand that if I have any questions about my rights or any other concern about the research, I can contact Robert C. Matthews, Institutional Review Board, at (225)578-8692.

I agree to be in the study described above. I understand that the researcher must give a signed copy of this consent form.

______________________________ ______________________________

Signature of Participant Date

APPENDIX C: ACCURACY BY ROAD SIGN

Road Sign	AG n = 10	Normal Group n = 10	Overall n = 20
	Number of Times Accurately Interpreted	Number of Times Accurately Interpreted	Number of Times Accurately Interpreted
Arrow Curve	5	7	12
Road Closed Ahead	4	10	14
Change in Speed Limit	6	10	16
Road Curves	6	10	16
Curve Left	8	9	17
Lane Ends	9	8	17
Left Only	8	9	17
Yield Sign Ahead	7	10	17
Flagman Ahead	8	10	18
Median Divided Highway	8	10	18
Median	8	10	18
No Right Turn	8	10	18
Curve Right	9	10	19
Evacuation Route	9	10	19
Four-Way Stop	9	10	19
Lane Splits	9	10	19
Railroad Crossing	9	10	19
School Zone	9	10	19
Speed Bump	9	10	19
Speed Limit	9	10	19
Stop Light Ahead	9	10	19
Bicycle	10	10	20

Do Not Enter	10	10	20
Handicap Parking	10	10	20
No Left Turn	10	10	20
No Parking	10	10	20
No U-Turn	10	10	20
One Way	10	10	20
Pedestrian Crossing	10	10	20
Roadwork Ahead	10	10	20
Slippery Road	10	10	20
Stop Sign Ahead	10	10	20
U-Turn	10	10	20

APPENDIX C: RESPONSE TIME BY SIGN

Road Sign	AG n = 10	Normal Group n = 10	Overall n = 20
	Mean Response Time	Mean Response Time	Mean Response Time
Arrow Curve	3320.22	1320.1	2267.53
Bicycle	1399.3	848.7	1124
Change in Speed Limit	6881	1264.2	3924.79
Curve Left	3096.78	1452.3	2231.26
Curve Right	1850	976	1436
Do Not Enter	2373.2	1096	1734.6
Evacuation Route	2773.6	1025.3	1899.45
Flagman Ahead	2803.78	961.1	1833.95
Four-Way Stop	5042	926	2984
Handicap Parking	2173.8	1152.3	1663.05
Lane Ends	3982.4	1068	2601.89
Lane Splits	1453.8	1109.3	1281.55
Left Only	2139.4	1619.5	1879.45
Median	2678.1	1264.8	1971.45
Median Divided Highway	2622.5	1117.4	1869.95
No Left Turn	5952.9	1286.2	3619.55
No Parking	1701.22	1304.67	1502.94
No Right Turn	3911.2	1377.9	2644.55
No U-Turn	2385.5	3399.6	2892.55
One Way	3692.56	1601.3	2591.89
Pedestrian Crossing	1546.7	976.7	1261.7
Railroad Crossing	1993.2	1079.2	1536.2

Road Closed Ahead	3179.2	1098.5	2138.85
Road Curves	3260	1169.7	2214.85
Roadwork Ahead	2508.8	1341.2	1925
School Zone	3903.8	883.1	2393.45
Slippery Road	2365	1149.78	1789.37
Speed Bump	2763.11	982.9	1826.16
Speed Limit	1787.6	1213.3	1500.45
Stop Light Ahead	1864	655	1259.5
Stop Sign Ahead	1808.7	1196.3	1502.5
U-Turn	1511.5	1093.2	1302.35
Yield Sign Ahead	3362.5	1422.4	2392.45

VITA

Caitlin Elise Brown was born in Metairie, Louisiana. She attended Louisiana State University where she earned her Bachelor of Arts degree in Anthropology in May 2011. She began her Master of Arts Degree in August 2012 at Louisiana State University and is a candidate to graduate in May 2015. Her thesis was completed under the guidance of Dr. Neila J. Donovan, Ph.D., CCC-SLP. Upon graduation, Caitlin plans to work as a speech-language pathology clinical fellow in an in-patient hospital setting with special interest in treating adults with neurogenic communication disorders. In the future, Caitlin hopes to continue doctoral studies with special interest in cognitive-communicative disorders following stroke and traumatic brain injury.